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AMBURSEN HYDRAULIC CONSTRUCTION COMPANY
ENGINEER - CONSTRUCTORS
176 FEDERAL STREET, BOSTON, MASS.
CITY INVESTING BUILDING, 165-7 BROADWAY NEW YORK

THE DAMS THAT FAILED

FRANKLIN INSTITUTE
PHILADELPHIA

Ambursen Hydraulic Construction Co.

Engineer-Constructors

176 Federal Street, Boston
165 Broadway, New York

THE DAMS THAT FAILED

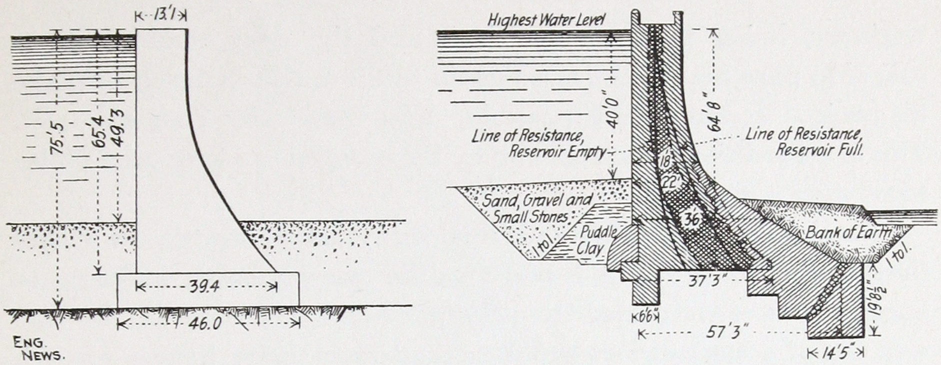
Said a prominent financial man to us recently:—

"It seems to me that you have but one remaining outpost to conquer, and you are then in full possession of the field. You must overcome the *sound* of that word 'SOLID'."

It is undeniable that the word "solid" has a booming and mighty sound. But remember that its origin was back in the days when hydraulic construction was evolving from earth or crib dams into something more permanent. As a comparative term, under those conditions, the word was convenient. But in so far as it describes the actual characteristics of the dam itself in relation to safety and permanence, it is a clear case of obtaining reputation under false pretences.

The number of "solid dams" which have gone out is appalling in respect to loss of property and life. Of course at the engineering inquest a reason can always be found,—or guessed at—but the lives are already extinguished and the property annihilated. Nevertheless, since water power *must* be developed, solid dams would necessarily have been built and rebuilt forever, with perhaps increasing lavishness in construction and less returns in investment had no further advance in hydraulic design been possible. But the reinforced-concrete dam has established hydraulic design for the first time on a strictly scientific basis, and with the most unusual accompaniment of a measurable reduction of cost.

Never lose sight of the fact that the solid dam in spite of the sound, is not inherently strong but *inherently weak.* Its apparent massiveness leaves a tremendous impression *on the eye,* while at the same moment it is the weakest of all known and accepted engineering structures. No other structure is tolerated under so low a margin of safety as the so-called "solid dam." The reason is a simple one,— the prohibitive cost of a larger safety factor which if carried out, takes the work clear outside of the range of investment. The

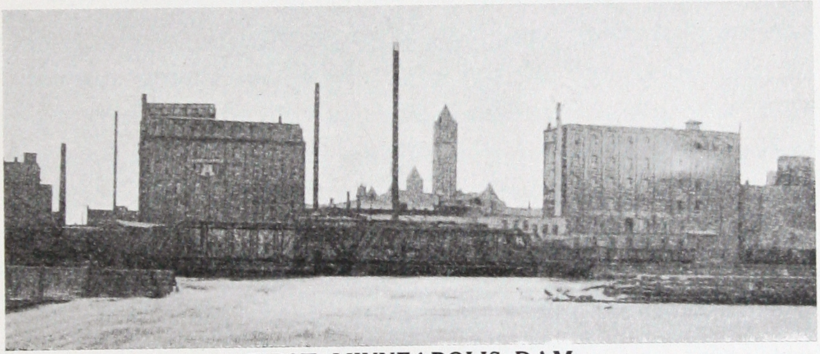


Before Failure

After Rebuilding

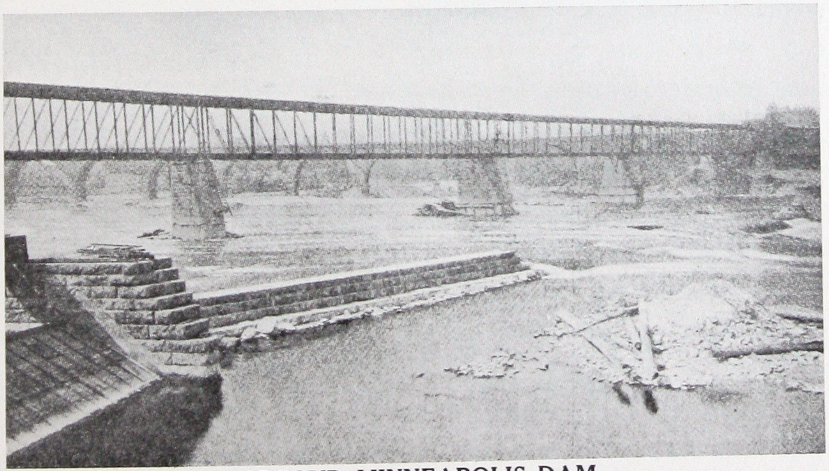
THE BOUZEY DAM, EPINAL, FRANCE

Fig. 1.
Failed April 27th, 1895



FIRST MINNEAPOLIS DAM

Fig. 2.
Failed March 31st, 1897



SECOND MINNEAPOLIS DAM

Fig. 3.
Failed April 30th, 1899

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engineer, being between the devil and the deep sea, has been *obliged* to pare his safety factor down to the quick in order to make his project commercially possible,—and familiarity does the rest. This is a condition which is not to be escaped so long as a dollar must earn a dividend.

Engineers all understand this fact — none better, — whether they admit it or not. Be it said that the overwhelming majority of engineers have welcomed the reinforced-concrete dam as the one way out of a most serious problem, and have been honest enough with themselves and with their clients to admit its value and incorporate it in their general designs. Our files are filled with spontaneous expressions from all over the world in recognition which the engineering profession has given to our work.

At the other end of the scale is a decreasing crowdlet of engineers whose conversatism is so extreme that they cannot permit themselves to acknowledge anything that lacks the sanction of antiquity. It has been well said that — "Certainty does not follow on demonstration,—it follows on habit." Habit, backed by individual timidity, will hold this type of engineer down to precedent, — always precedent, — forgetting that engineering always advances, and that the supremacy of the United States is due in large part to the bold brain and the sure hand of its engineers who know their business well enough to rely on *themselves.* We may not hope to budge this type of mind until it is smoked out by the irresistible logic of results.

In between the two is a thin stratum of engineers who have an eye single to their personal interest and to that only. Being ourselves engineers, we are proud to say that this particular stratum is so thin as to be negligible.

However in this pamphlet we are not speaking to the engineer but to the Banker and Capitalist. We are not even attempting a demonstration, although we shall briefly outline the why and wherefore after exhibiting the facts.

Let us examine the records. We have been at some pains to collect the raw history of dam failures from the single source of the

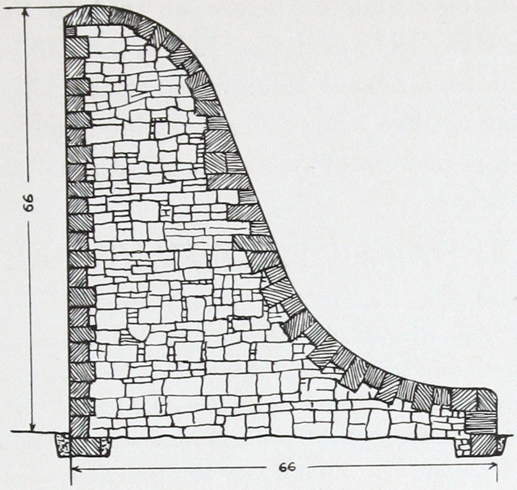
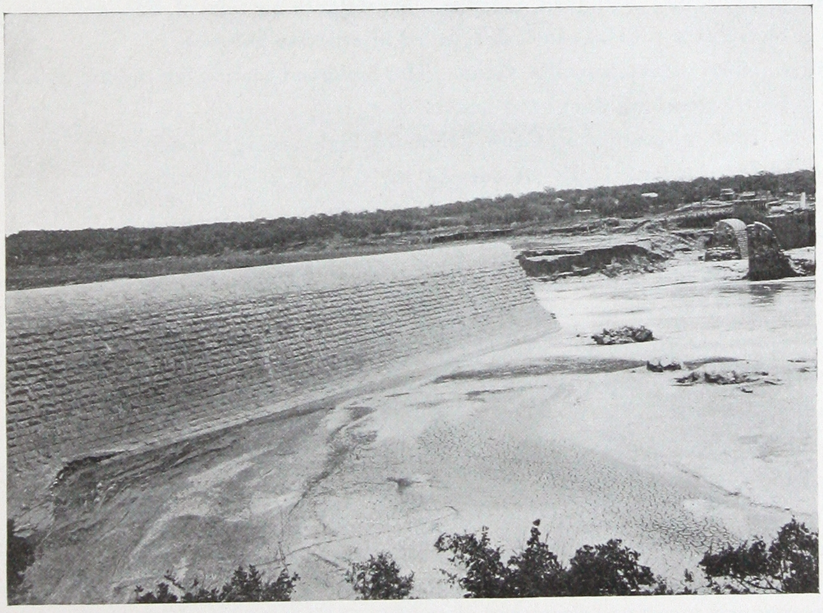


Fig. 4. SECTION OF THE AUSTIN DAM



AUSTIN DAM

Fig. 5. Failed April 7th, 1900

technical journals, confining ourselves at that to the files of the ENGINEERING RECORD and the ENGINEERING NEWS from Jan. 1, 1890 to date, a period of eighteen years. The following is the tabulated result. We ask you to examine it with an open mind and see if your impressions of what constitutes a "solid dam" are not severely modified.

"SOLID DAMS" THAT HAVE FAILED.

March 1891. Portland, Me. Dam 25' high and 175' long.

December 22, 1892. Pine Ridge, Calf. Dam 37' high, 100' long, 40' thick at base.

March 13, 1894. Dam on Indian Creek, Boise, Idaho. No details.

★ April 27, 1895. Epinal, France. The Bouzey dam, 72' high, 1700' long, 63' thick at the base, 13' at the top, failed from under-pressure on the base.

October 10, 1895. Scranton, Pa. Rubble masonry with dressed granite face.

★ March 31, 1897. Minneapolis, Minn. across the Mississippi River.

★ April 30, 1899. Minneapolis, Minn. across the Mississippi River. Dam of ashlar masonry, 20' high, 535' long.

★ April 7, 1900. Austin, Texas. Across the Colorado River. This dam of first class masonry 65' high and 1100' long is one of the most notable failures in history.

November 16, 1900. Richelieu, Quebec. Waste gate section of this dam failed on above date. (The entire dam failed later. See below.)

March 18, 1901. Danielsonville, Conn. The bulkhead section of the 20' dam failed partly wrecking the power house.

March 12, 1902. Manchester, Conn. Dam 30' high and 175' long.

June 8, 1902. Ashland, N. H. A dam 14' high.

July 15, 1902. Caro, Mich. Dimensions not given.

★ November 30, 1902. Richelieu, Quebec. One section of this dam 28' high went out entirely. NOTE. In 1905 we rescued the remaining 1100 feet from complete failure by enclosing it on the upstream side and crest with a body of reinforced concrete.

★ December 28, 1902. Tallahassee, Ala. Tallapoosa river. Height 30'. Length 500'.

December 28, 1902. The upper dam belonging to the same company failed on the same date. Dimensions not given.

★ December 28, 1902. Anderson, S. C. Seneca River. Dam 40' high and about 600' long.

★ December 28, 1902. Columbus, Ga. Chattahoochee River. Dam 40' high.

NOTE. On this day the floods due to a heavy storm swept out the four large dams mentioned above and a number of smaller ones, data on which we are unable to obtain.

★ Illustrated in this brochure.

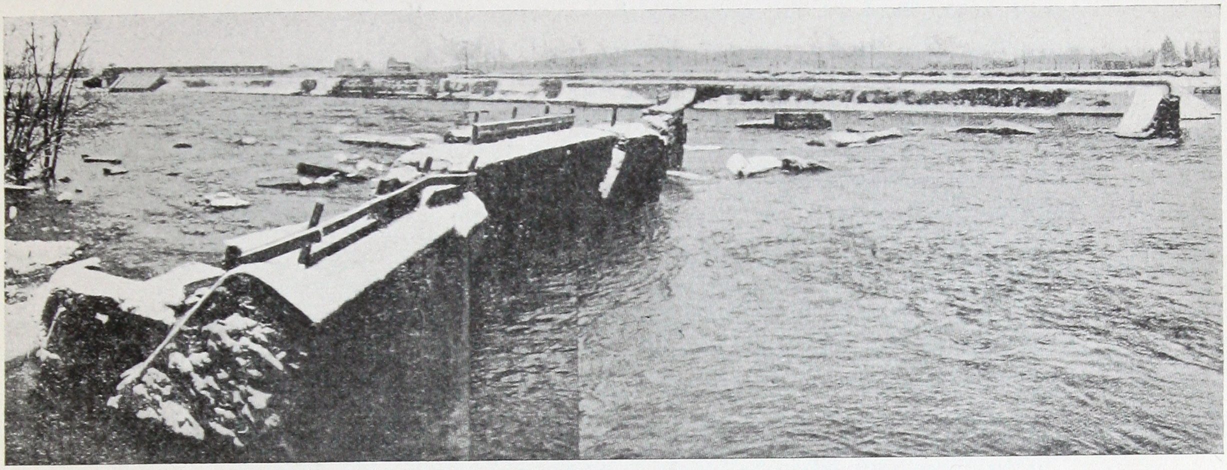


Fig. 6. CHAMBLY DAM Failed Nov. 30th, 1902

NOTE. In 1905 we rescued the remaining 1100 feet from complete failure by enclosing it on the upstream side and crest with a body of reinforced concrete. The portion saved by us is seen in the background, extending the whole width of the picture. Over 8000 yards of concrete we laid in the middle of a Canadian winter, by divers under twenty feet of water, without interrupting service for a moment.

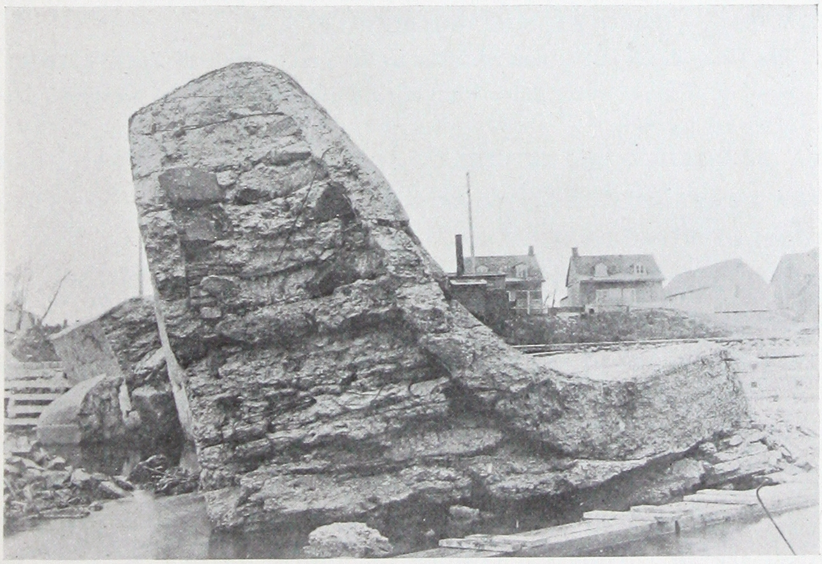


Fig. 7. SECTION OF CHAMBLY DAM

April 1, 1903. Roxbury, Vt. Dam 24' high.

September, 1906. Dam at Durango, Mexico. 15' high.

★ August 23, 1907. Traverse City, Mich.

★ DAYTON, OHIO. We made proposals for a small reinforced concrete dam which were not accepted. Work done by local contractor and part of dam washed out before completion.

The following failures not found in the records, have come within our own observation.

STROUDSBURG, PA. This dam about 20' high failed entirely and we were invited to consider rebuilding it but could not reach an agreement with the owners.

★ DECORAH, IOWA. We made proposals for this dam which were not accepted. The dam was subsequently built by a local contractor and went out entirely shortly after completion, wrecking the power house.

DELHI, ONTARIO. We also made proposals on this dam without success. The dam was partly destroyed during construction January 1906, and after completion was again washed out on August 11, 1906.

ROCK HILL, S. C. A large masonry dam failed at this point in or about 1900 but dimensions not known.

MUSCODA, WIS. Masonry dam reported as failed at this point but dimensions not given.

KALAMAZOO, MICH. Dimensions and reasons for failure not known.

ORILLIA, ONTARIO. This dam failed April 7, 1904, we are informed shortly after completion.

CLIFTON, S. C.—PACOLET, S. C.—GLENDALE, S. C.

The three dams above named failed in the great storm of June 6, 1903. A number of other lesser dams went out on the same date of which no particulars are known.

TOTAL. 32 SOLID DAMS REPORTED AS HAVING FAILED IN 18 YEARS.

Now as against the above exhibit what has the reinforced concrete dam to offer?

In the first place we have built at this moment of writing forty-one dams. It is needless to say that not one of them has gone out or shown the slightest wavering under extraordinary conditions. Note only one or two of these extraordinary instances.

In 1905 we built a small dam at Russell, Mass., on the Westfield River. Figure 14 shows the behavior of this dam under very peculiar circumstances. The dam not being completed the water was discharging through a couple of sluice gates. A mild rain caused a gradual rise in the river, starting the ice and bringing it

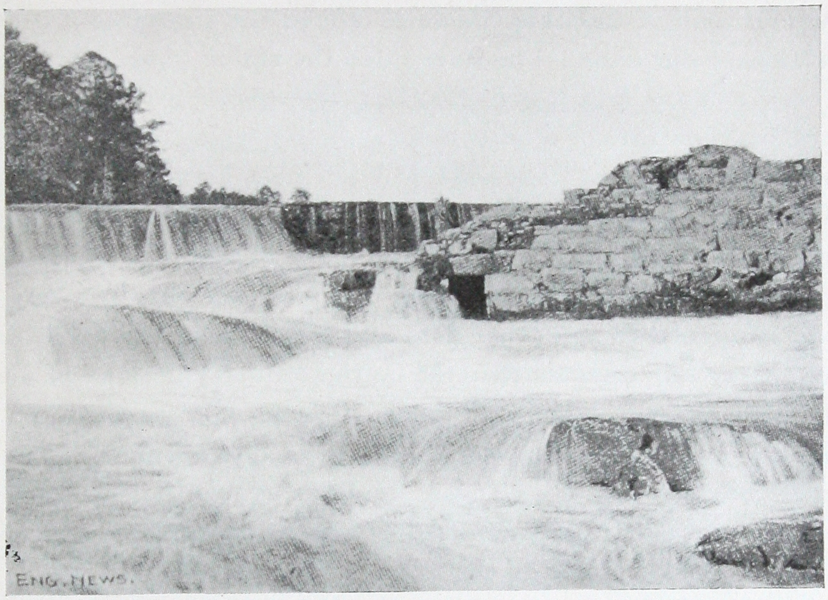
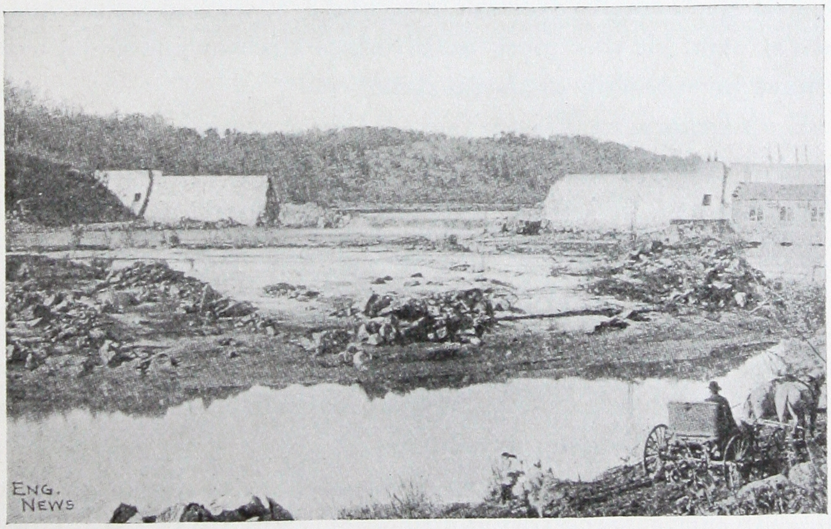


Fig. 8. TALLAHASSEE DAM
Failed Dec. 28th, 1902 The fragment in the foreground is the dam



ANDERSON DAM
Fig. 9. Failed Dec. 28th, 1902

down for many miles over the dams above and stranding it ten feet thick above our dam. The river filled the sluice gates and backed up on the dam about half its height. The quick water started the entire mass of ice for a mile and a half upstream. Striking the dam it was unable to float over it but the pressure was so great that the whole mass of ice amounting to thousands of tons was *forced dry* over the crest! We are obliged to make a wash drawing to illustrate this unusual "dry test," which very possibly has never happened to any other dam and which certainly would have swept away any dam constructed on the ordinary designs of a solid dam with a vertical back. Figure 15 is a photograph taken the following day, after the water had gone down and the ice had slipped back.

Two years later another ice gorge went out at least 15' deep leaving the standing ice on the banks as shown in Figure 16.

Figure 17 was taken a day or two later showing a mass of ice lodged on the top of the abutment. The same ice gorge lifted a steel highway bridge from its piers, carried it down over the dam, dropping one span squarely on the crest where it remained for some time. It finally overbalanced and was carried a long distance down stream. It was most unfortunate that a photograph could not have been caught at that instant.

Furthermore, as it was feared the excessive flood would do damage in that vicinity an attempt was made to blow out two bays of the dam with dynamite but without any effect whatever.

In this connection we have just been told by the owners that on our Patapsco dam a heavy stump which had lodged in one of the waste gates was blown out with a charge of three sticks of dynamite without a trace of damage. In fact, how can you blow up or in any way wreck a structure that is laced through and through with steel every four to six inches?

Figure 18 shows the Missisquoi dam under flood. This dam ordinarily carries each spring a flood of from 12' to 13'. The dam itself is 42' high in the center and 270' long. It is almost on the line between Vermont and Canada. Three dams have been

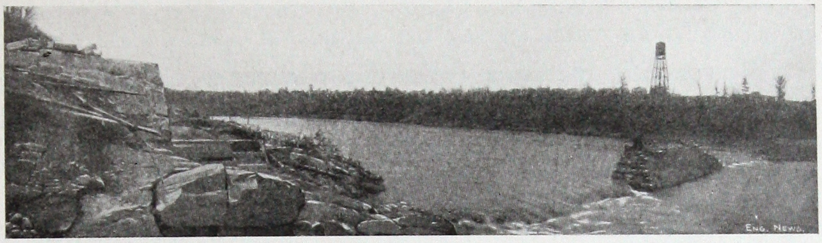


Fig. 10. COLUMBUS DAM Failed Dec. 28th, 1902

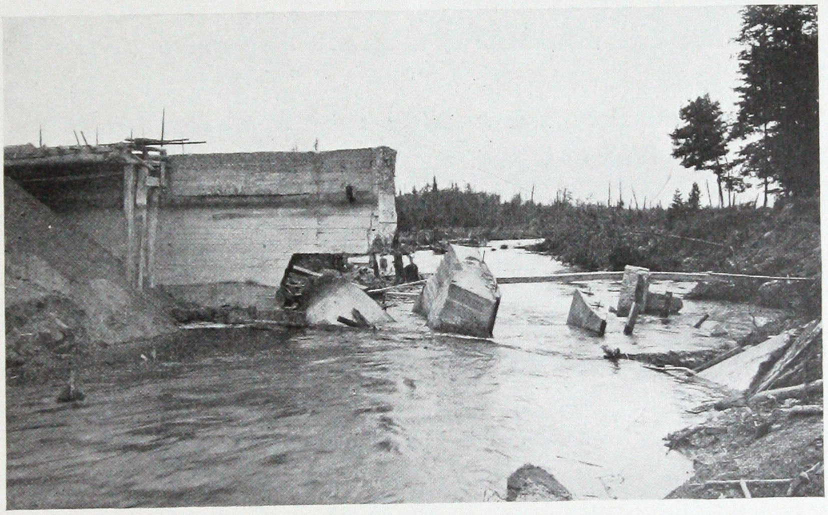


Fig. 11. TRAVERSE CITY DAM Failed Aug. 23d, 1907

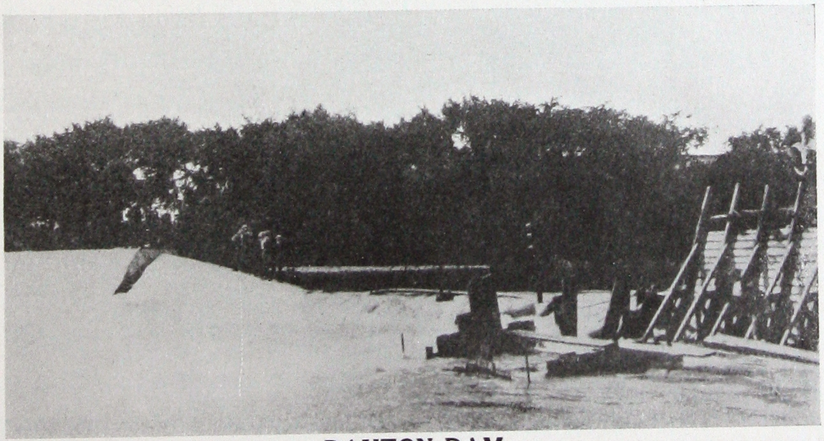


Fig. 12. DAYTON DAM
Washed out during construction

carried out in succession at this site within seven years by an ice gorge which forms each spring on an island half a mile above the dam. We recently received from the owners a letter advising us of a recommendation which they had given to a prospective client, from which we quote as follows. "We believe we have not advised you that our dam received the heaviest run of ice last Spring we have seen on this river for ten years. The structure came through without a scratch and we do not think it was harmed in the least."

The same tale would apply to practically every dam we have built.

It is a physical impossibility for a reinforced concrete dam properly designed and built to go out under any conditions of flood or ice gorge.

Why this is so is an engineering question. Very briefly however we will make the principal points clear to the lay mind.

A reinforced-concrete dam cannot over-turn, whereas a solid dam is, so-to-speak, always on the verge of overturning; that is it is *always,* even under *normal* conditions, at the *extreme limit* of safety.

Figure A is the standard section of a solid dam and the heavy line shows the position of the resultant force for which the dam is designed. (A solid dam is often extended in a curved toe which, however, adds nothing to the strength but is merely for purposes of deflecting the water.) The dam is so designed that the resultant is exerted at a point one third the distance from the center of the base to the down stream edge. The pressure on the base may be represented by the shaded triangle, being zero

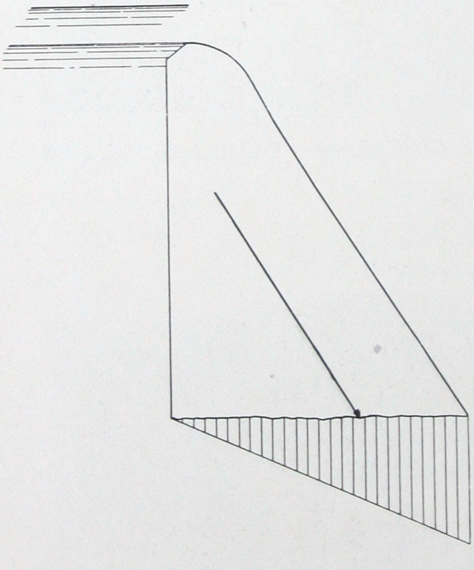


Fig. A. Base Pressure on Solid Dam.

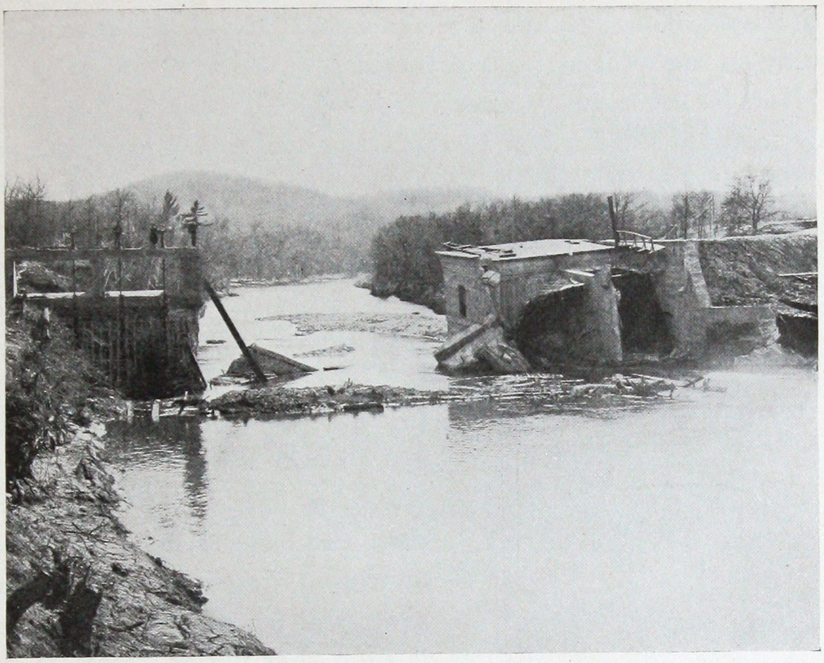


Fig. 13. DECORAH DAM AND POWER HOUSE

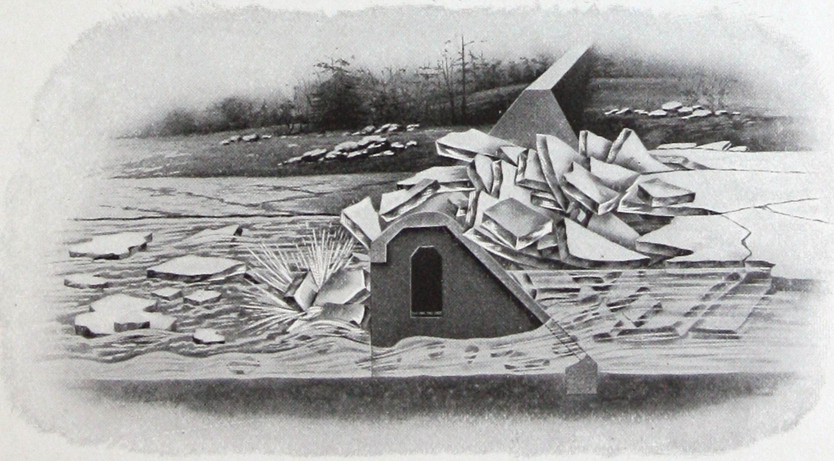


Fig. 14. RUSSELL CONCRETE-STEEL DAM

Dry ice shove in progress

at the upstream edge and a maximum at the down stream edge; exactly on the weakest part of the dam.

Now let there be an excessive flood,—the resultant is immediately crowded still further towards the toe, as in Fig. B, the pressure exceeds the safe strength of the material, the toe crumbles thus shortening the effective base, the heel of the dam lifts and the dam overturns. (Usually the actual failure is by a combination of sliding and overturning but this will serve for an illustration.)

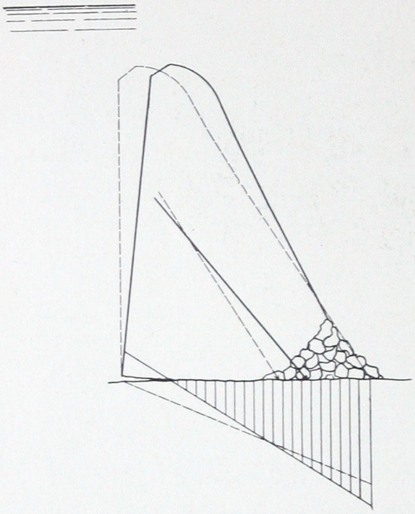


Fig. B. Excessive Pressure Causing Overturn.

Now in a reinforced-concrete dam the base is more than twice as wide. Moreover the resultant is always *at the center,* and the design is such that under excessive flood the resultant instead of moving down stream towards danger moves upstream towards safety. By no possibility therefore can a reinforced-concrete dam overturn. For illustration of the above, see Fig. C.

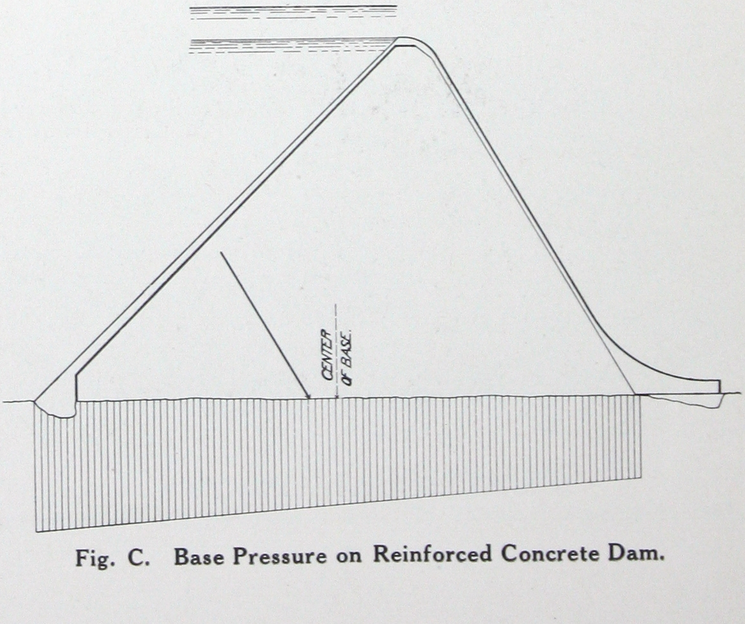
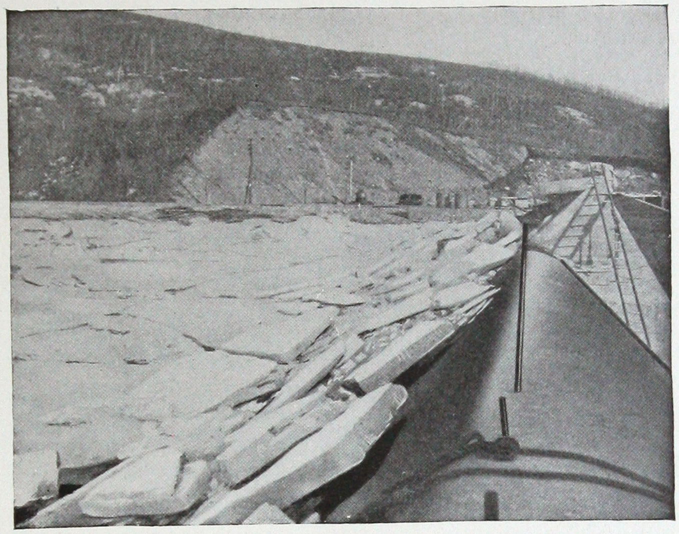


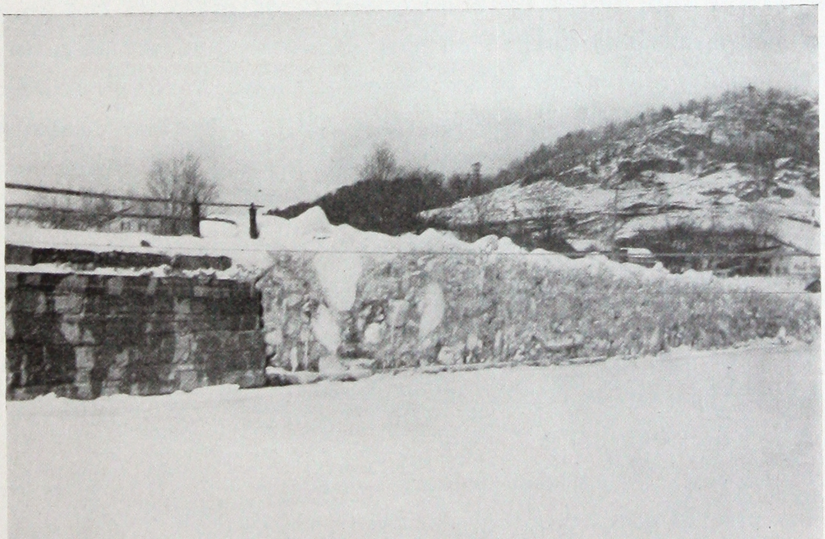
Fig. C. Base Pressure on Reinforced Concrete Dam.



RUSSELL DAM

Fig. 15.

After ice shove



RUSSELL DAM

Fig. 16.

Showing walls of ice shove 15 feet high

A reinforced-concrete dam cannot slide on its base. In a solid dam the whole pressure of the water is exerted horizontally against the dam which must therefore be locked into its foundations by excavation.

But on a reinforced-concrete dam the water pressure is exerted *partly downwards,* pinning the dam on its foundations. Hence the greater the flood the more stable the dam,—not a paradox but a literal truth. The resultant can thus always be kept within the angle of friction and a dam of this type can not slide on its foundation even if the latter is as smooth as a concerte sidewalk.

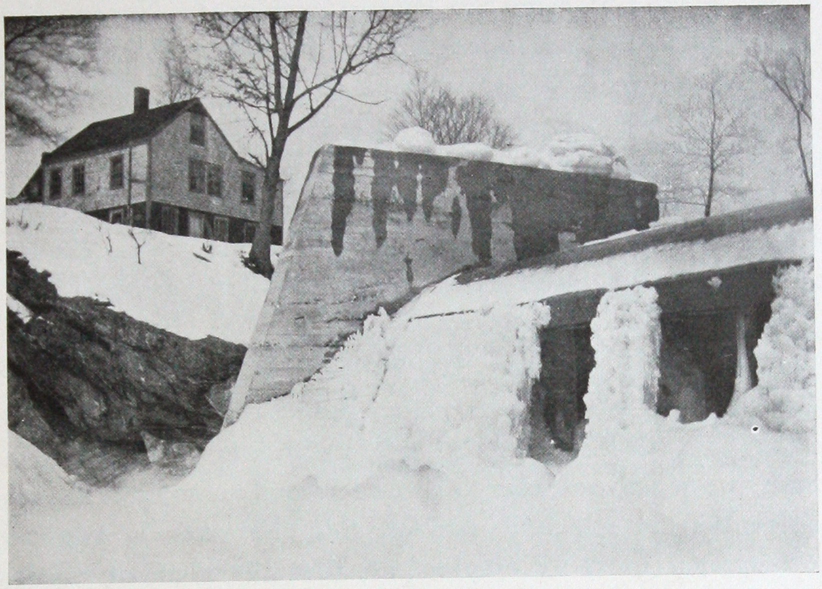
A reinforced-concrete dam cannot float out. Many a solid dam has been lifted partly from its base by the upward pressure of water working underneath it. This condition can never be surely detected in a solid dam and when it exists the dam is certain to fail. A reinforced-concrete dam cannot be floated out *because it has no base* on which the water can act.

A reinforced-concrete dam cannot fail by crushing. This is merely a question of the distribution of unit stresses, i. e.—pressures per square foot, tension per square inch, etc. On account of better distribution and hence reduced quantity of material the modern dam is commercially able to employ factors of safety of from 2 to 2½ times as great as are used in solid dams; in other words the pressure per foot is half, or less than half, of that in a solid dam.

A reinforced-concrete dam cannot fail by hidden defects. Since every part of the interior of the dam can be inspected foot by foot, it follows that there can be no defects which will not instantly betray themselves, a feature possessed by no other design. This point of inspection is regarded by all engineers as of great value.

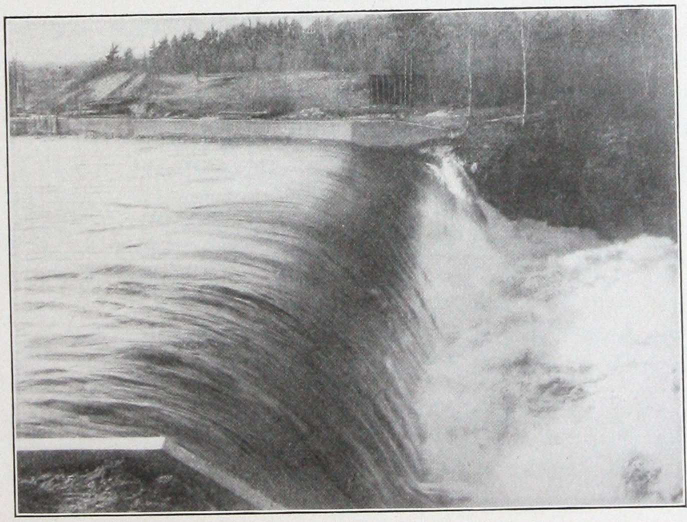
In short, reinforced-concrete is the last word of the engineering profession in respect to that peculiar quality of strength best described as "toughness."

Have you ever stopped to consider the enormous application of this material in great modern structures of all kinds? For instance the Viaduct of the Florida Coast Railway from Miami to Key West. In this viaduct there are 36 miles of reinforced-concrete arches standing in salt water and carrying not only the moving load of the trains but resisting the assault of the sea waves.



RUSSELL DAM

Fig. 17. Showing ice on abutment



MISSISQUOI DAM

Fig. 18. Under half flood

Consider the Galveston Sea Wall. Consider the Hudson Memorial Bridge to span the Harlem River with a clear arch of 720 feet.

The number and variety of such structures representing millions of investment is beyond computation and reinforced-concrete is the universal material selected.

It only remains to say that the conditions surrounding the construction of a dam from this material are simplicity itself as compared with such illustrations as those above cited.

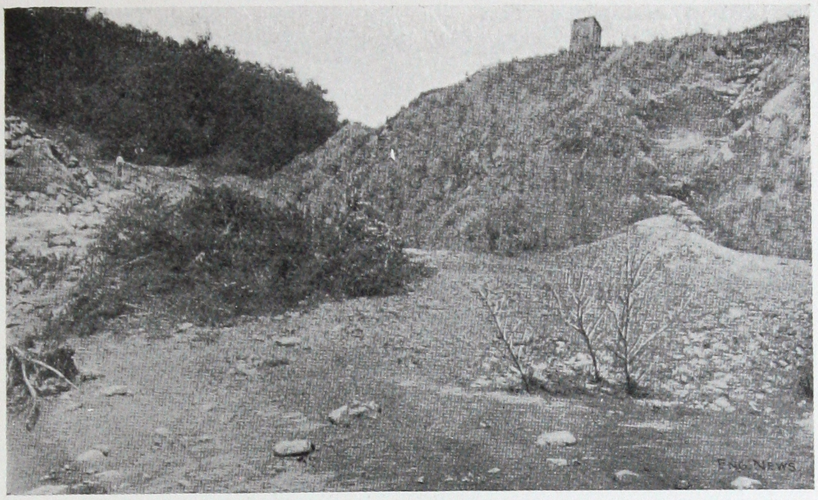
EARTH DAMS THAT HAVE FAILED.

Our investigation of the record of failures of solid dams carried with it similar failures of earth dams. Earth and corewall dams are still built and we do not wish to be understood as saying that there is no location in which a dam of this character is applicable. Nevertheless, it must be emphasized that the element of risk is always present in this type of dam as in the solid dam,—a risk which we most sincerely believe is absolutely eliminated for all time by the concrete-steel dam.

Without further comment we submit the list of earth dams which have failed with a few illustrations:—

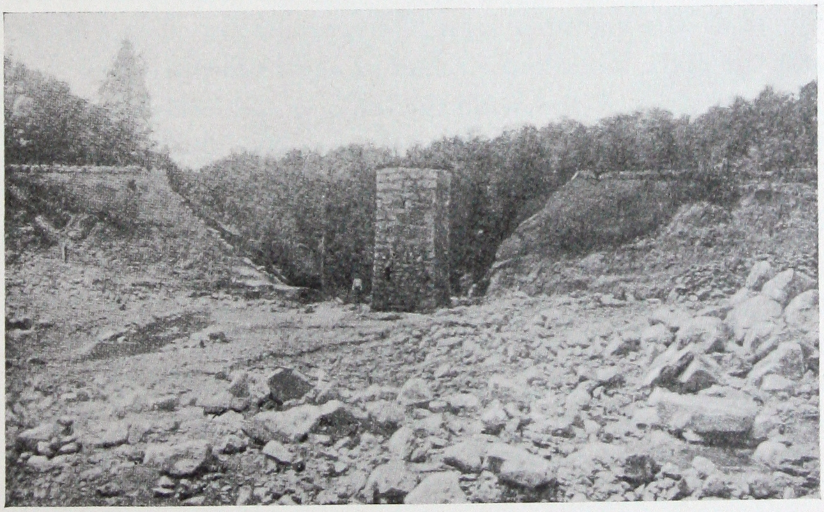
EARTH.

May 10, 1890	Nebraska City, Neb. Two dams. 17' high each.
May 21, 1890	Gunnerson, Cal.
Aug. 1891	South Fork, Pa. (Cause of Johnstown Flood.)
June 4, 1892	Spartansburg, Pa.
Aug. 6, 1893	Portland, Me. 45' high.
May 1894	Lima, Mont.
May 25, 1894	Avoca, Pa.
Nov. 3, 1894	Ansonia, Conn. 40' high.
★ July 14, 1897	Matteawan, N. Y. Two dams, respectively 28' high and 340' long, and 34' high and 400' long.
Oct. 1898	Snake Ravine, Cal. 64' high.
July 2, 1900	Grand Rapids, Mich. 30' high.
Oct. 1900	Wilmington, Del. 10' high.
Mar. 11, 1901	Providence, R. I. Two dams respectively 17' and 18' high.
Apr. 21, 1901	Middlefield, Mass. 30' high.



MATTEAWAN UPPER DAM

Fig. 19. Failed July 14th, 1897



MATTEAWAN LOWER DAM

Fig. 20. Failed July 14th, 1897

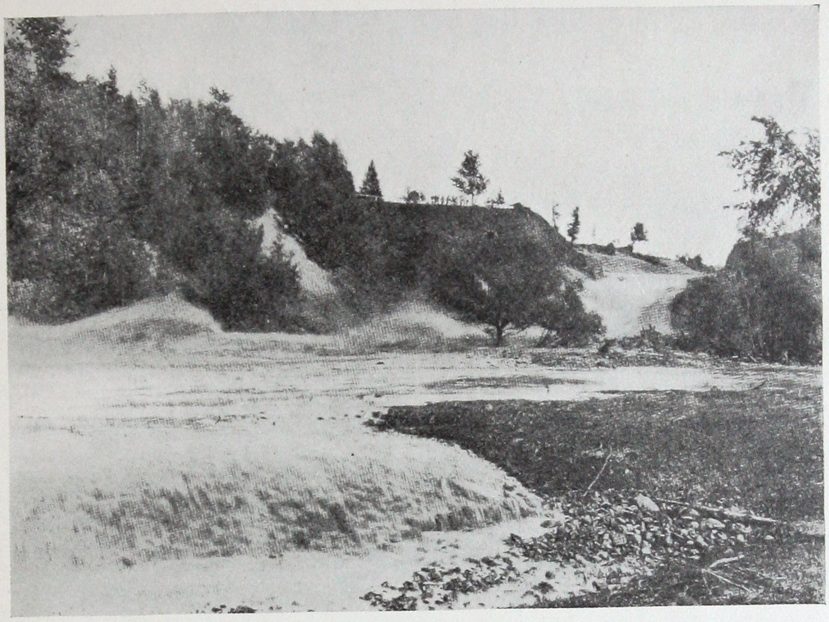
	May 19, 1901	Wichita Falls, Tex.
	Oct. 13, 1901	East Liverpool, Ohio.
	May 29, 1902	Connellsville, Pa.
★	Sept. 17, 1902	Utica, N. Y. 70' high.
	Oct. 1902	Camden, N. J.
	Feb. 22, 1903	Shelton, Conn. Two dams 25' high and 110' long.
	Apr. 11, 1903	Delta, Colo. 34' high. Two years old.
	May 16, 1903	Circleville, Utah.
	May 16, 1903	Lemont, Pa.
	July 5, 1903	Jeannette, Pa.
	Dec. 15, 1903	Heledon, N. J.
★	July 17, 1904	Scottdale, Pa. 60' high.
	May 1905	Hotchkiss, Colo. Two dams 30' high.
	July 1905	Bridgeport, Conn.
	Sept. 3, 1905	Sherburne, N. Y. Two dams. 34' high.

TOTAL.—35 EARTH DAMS FAILED IN 18 YEARS.

Fig. 23 illustrates the first step of a possible failure in the reservoir dam at Altoona, Pa. This is a dam situated in the famous Horse Shoe Curve of the Pennsylvania Railroad and is plainly visible from the tracks. On May 20, 1894 a heavy wind blew down the gorge between the mountains and literally shoved the water of the reservoir over the crest of the dam. In a few minutes the earth bank had washed as shown in the cut and except for the subsidance of the wind the dam would undoubtedly have been carried away. This is one of the peculiar ills that the earth dam is heir to. It is questionable if an earth dam built of such a height as to be above the possibility of over-topping by circumstances of this character, would be any lower in cost than the permanment concrete-steel dam. However, we are not rabid on this point and promptly concede the value of the earth dam in any location where its use is indicated.

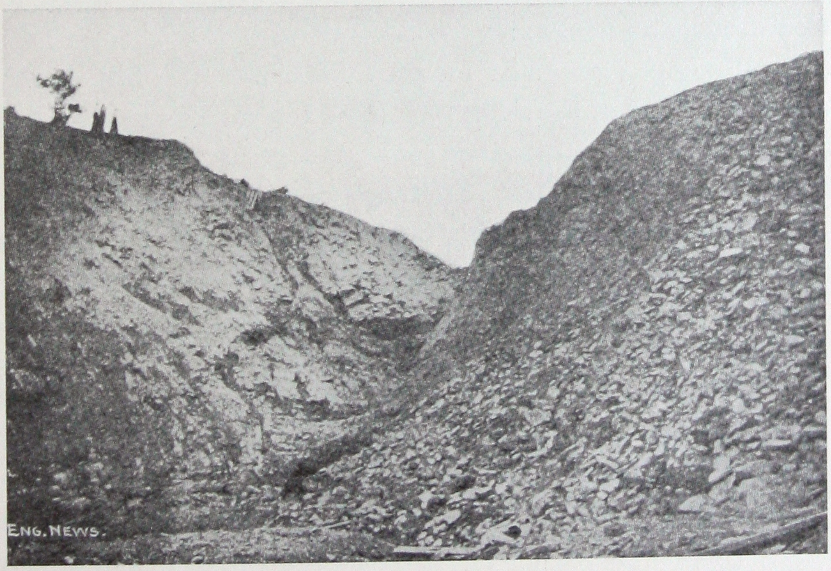
ROCK FILL DAMS THAT HAVE FAILED.

★ Feb. 22, 1890. Walnut Grove, Arizona. Dam 110' high. The illustration Fig. 24 is from a photograph made before the



UTICA DAM

Fig. 21. Failed Sept. 17th, 1902



SCOTTDALE DAM

Fig. 22. Failed July 27th, 1904

dam failed. The failure was complete and the destruction wide spread.

Aug. 6th. Eddy, New Mexico. Dam 45' high and 1040' long over the Pecos River.

CRIB DAMS THAT HAVE FAILED.

The number of crib dams that are recorded as failing is no indication of the number actually failing. A crib dam, or a wooden dam in any form, has a limited life and is expected to fail in the natural course of events. Very few of these failures reach the engineering press but our own correspondence alone shows that a very large number fail every spring.

Among the most notable failures were the dam at Colburn City, Wisconsin, 15' high and 1100' long which failed two years after construction.

Another was the complete failure of a crib dam 65' high and 500' long at Butte, Montana, in Feb. 1898.

The general statement which will apply to a crib dam is well summed up in the "Engineering Record" of Oct. 25, 1902, from which we quote as follows:—

"Timber dams generally have an indefinite life but Mr. J. N. G. Watts, member of the A. S. C. E. has recently pointed out that it is just the few exceptions that cause the great trouble. He has been compelled to tear out thousands of feet of good timber in order to get down to the rotting sticks to strengthen a structure's stability,—hence a concrete dam is preferable."

STEEL DAMS THAT HAVE FAILED.

There have been only two or three all-steel dams built,—that is, dams built wholly of structural steel as a bridge is built. The unfitness of steel for hydraulic work is illustrated by the failure of the Hauser Lake Dam in April, 1908, an illustration of which is given below. The unfitness of structural steel, both in the uncertainty of distribution of stresses and the relatively rapid deterioration is now so well recognized that probably no other dams of

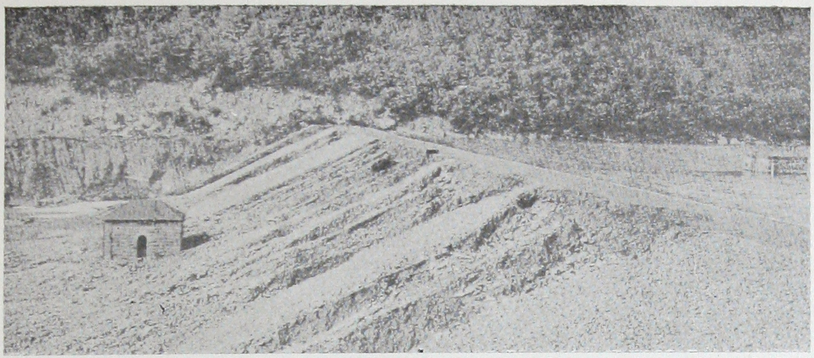
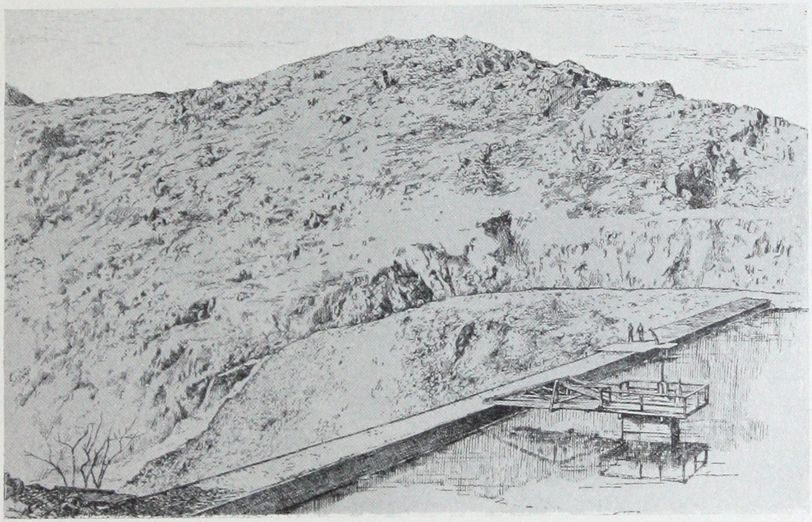


Fig. 23. ALTOONA DAM Showing incipient failure



WALNUT GROVE DAM

Fig. 24. Taken before failure, Feb. 22d, 1908

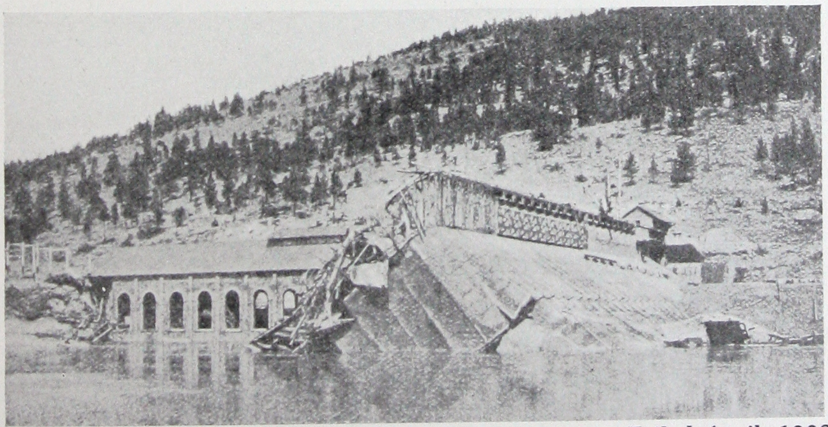
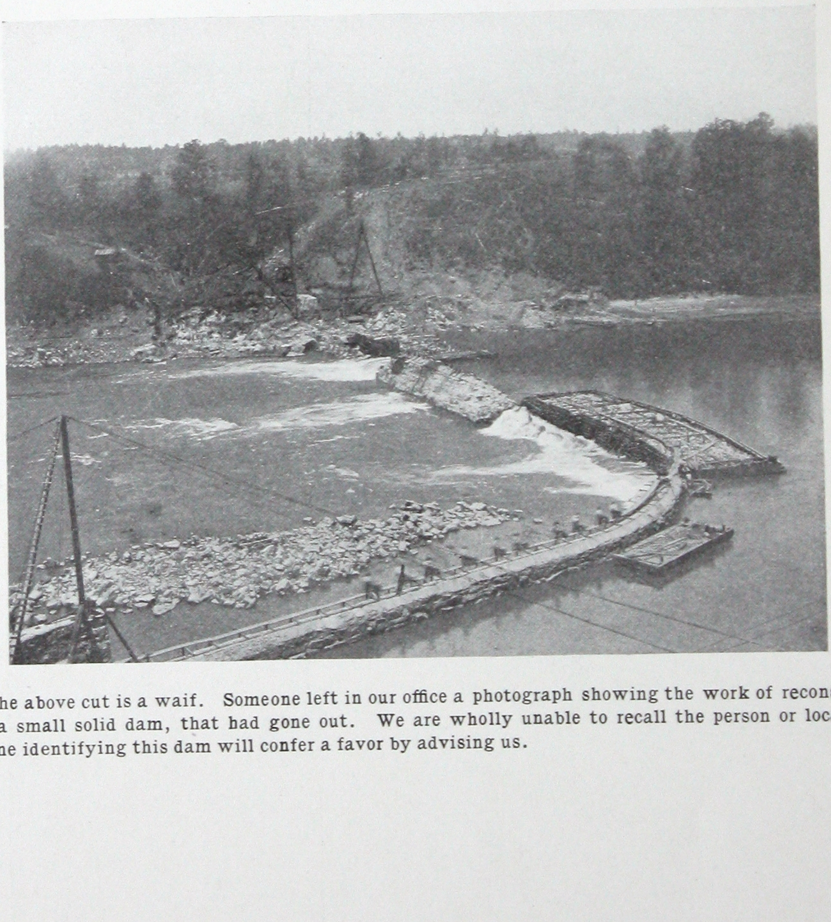


Fig. 25. HAUSER LAKE DAM Failed April, 1908

this type will be built. We mention it here merely by way of completing the record.

In addition to the specific instances above enumerated we find records of 31 dams that have failed within the limit of eighteen years, but of which no description is given either as to their height, material or causes of failure. The probability is that the cases were insignificant.



The above cut is a waif. Someone left in our office a photograph showing the work of reconstructing a small solid dam, that had gone out. We are wholly unable to recall the person or location. Anyone identifying this dam will confer a favor by advising us.